Abstract

Vibration control is the method of imparting damping in a structure to achieve vibration free state. In active control method, the structure is incorporated with controllers, actuators and sensors. The actuator will exert necessary force or moment on structures according to feedback signal from controllers and hence desirable performance can be achieved. In this thesis, a new method is followed to design an active control system which imparts viscoelastic phenomenological damping in an elastic structure. Properties of a hypothetical viscoelastic system are used to design an active feedback controller for an undamped structural system with distributed sensor, actuator and controller. The variational structure is projected on a solution space of a closed-loop system involving a weakly damped structure with distributed sensor and actuator with controller. These controller components assign the phenomenology based on internal strain rate damping parameter of a viscoelastic system to the undamped elastic structure.

An elastic cantilever beam with proportional-derivative controller and displacement feedback is considered in all the design formulations. In the first part of the research, a closed-loop control system is designed using two time domain modern control system design methods, pole placement and optimal pole placement, which use viscoelastic damping parameter. Equation of motion of a viscoelastic system is employed to synthesize the desired closed-loop poles. Desired poles are then assigned to an elastic beam with an active controller. Time domain finite element formulation is used without considering actuator-sensor dynamics and the effect of transducer locations. Characteristics of closed-loop system gains are found as a function of desired damping parameter and

realization of damping have been analyzed with closed loop system pole positions.

The next part consists of a novel frequency domain active control system design to impart desired viscoelastic characteristics, which uses spectral method and the exact dynamic stiffness matrix of the system. In the first case, a sub-optimal local control system for a cantilever beam, with collocated piezo actuator and piezo sensor is designed. In the second case, a closed-loop local controller for an elastic system with non-collocated transducers is designed. Next, a global controller for non-collocated arrangement of sensor-actuator is designed by considering all the degrees-of freedom in the the system, which leads to solving an eigenvalue problem. The reason for the failure of the collocated arrangement in global control is also explained. In this novel control system design method piezo transducer dynamics and locations are considered in the formulation.

In frequency domain design, the frequency responses of the system show satisfactory performance of the closed-loop elastic system. The closed-loop system is able to reproduce the desired viscoelastic characteristics as targeted in the design. Optimal and sub-optimal system gains are found as functions of transducer locations, transducer properties, excitation frequency and internal strain rate damping parameter of a hypothetical viscoelastic system. Performance of the closed loop system is established by comparing the specific damping capacity of the hypothetical viscoelastic system with that of the closed-loop elastic system. The novel frequency domain method is simple, accurate, efficient and can be extended to complex structures to achieve desired damping. The method can be a better way of designing structures with variable stiffness which has research potential in designing morphing airplanes/spacecrafts. The ultimate goal of this research is that, if this design method is applied to practical applications such as aircraft wings, where vibration is undesirable, one would be able to achieve strength and desired damping characters simultaneously.